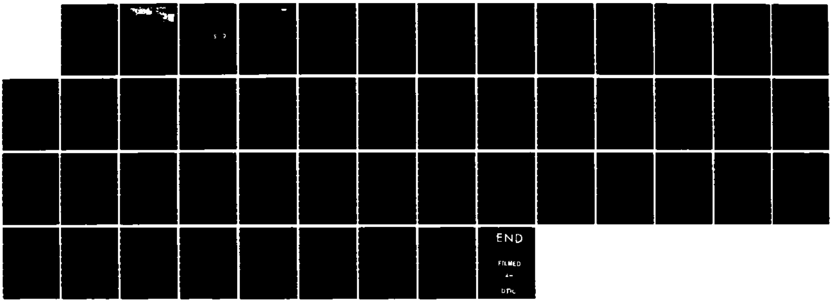
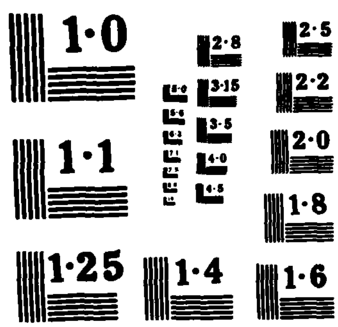
AD-A162 995 THE INFLUENCE OF SYSTEMS SUPPORT DIVISION FUNDING AND SAFETY LEVELS ON AIRCRAFT AVAILABILITY(U) LOGISTICS MANAGEMENT INST BETHESDA MD C H HANKS OCT 85 1/1

UNCLASSIFIED LMI-AF501-1 MDA903-85-C-0139 F/G 5/1 NL




1·0
1·1
1·25
1·4
1·6
1·8
2·0
2·2
2·5
2·8
3·15
3·5
4·0
4·5

AD-A162 995

THE INFLUENCE
OF SYSTEMS SUPPORT DIVISION FUNDING
AND SAFETY LEVELS
ON AIRCRAFT AVAILABILITY

LOGISTICS
MANAGEMENT
INSTITUTE

(12)

THE INFLUENCE OF SYSTEMS SUPPORT DIVISION FUNDING AND SAFETY LEVELS ON AIRCRAFT AVAILABILITY

October 1985

Christopher H. Hanks

Prepared pursuant to Department of Defense Contract MDA903-85-C-0139 (Task AF501-1).

LOGISTICS MANAGEMENT INSTITUTE
6400 Goldsboro Road
Bethesda, Maryland 20817-5886

Executive Summary

THE INFLUENCE OF SYSTEMS SUPPORT DIVISION FUNDING AND SAFETY LEVELS ON AIRCRAFT AVAILABILITY

Aircraft availability rates are not particularly sensitive to normal fluctuations in funding for the Systems Support Division (SSD) of the Air Force stock fund. We estimate that for each $9 million in peacetime Obligational Authority (OA) that is not approved in an SSD budget request, the average number of aircraft awaiting the repair of a recoverable component or subsystem increases (a leadtime later) by at most one aircraft. This applies to a total Air Force fleet of more than 7,500 aircraft. The reason is the largely indirect role played by SSD items in the resupply system for supporting aircraft, coupled with substantial management flexibility on the part of the Air Force Logistics Command (AFLC) to accommodate a short-term SSD funding constraint without seriously affecting end-item readiness.

The SSD finances wholesale and retail supply levels for the set of consumable repair parts assigned to the Air Force for management in the Department of Defense supply system. Although some SSD items apply directly to aircraft at the organizational level of maintenance, most SSD items serve as repair parts for other, reparable components and subsystems that have been removed from aircraft and are undergoing depot-level or base-level repair. Thus, for the most part SSD items play an indirect role in the support of aircraft.

Our estimate applies *only* in the case of a moderate -- up to 15 percent -- one-time, single-year reduction in SSD OA. In that case, AFLC has the flexibility to accommodate a funding constraint without lowering gross stockage requirements, mainly by ordering a temporary reduction in order quantities. Moderate reductions in order quantities allow the SSD to postpone some orders until a succeeding year, thereby reducing obligation outlays in the year in question and satisfying the budget constraint, without lowering overall stockage requirements.

Large one-time reductions in OA or repeated reductions over successive years would, in effect, reduce reorder points. This would represent a *de facto* lowering of SSD safety levels and the protection they provide against stockouts during procurement leadtime. When SSD safety levels fall, the effects on aircraft availability rates are five to six times greater than when order quantities are reduced.

Accordingly, the results should *not* be interpreted to mean that current SSD budget requests are too high or that they can be cut permanently without adversely affecting aircraft readiness. The results reflect only that a "budget cut" for the SSD is normally a constraint on OA outlays in a single year and that such a cut, if moderate, can be managed without causing serious reductions in customer support.

This is not to say there is no room for improvement in SSD operating policies. More important to aircraft availability than a fluctuation in SSD funding is the effect of AFLC policy for computing SSD safety level requirements. Since FY80, there has been a steady increase in the average number of outstanding SSD backorders at the wholesale level, even in periods when requested OA for the SSD was fully approved. The cumulative size of the increase (from an average of 104,000 outstanding requisition backorders in FY80 to an average of 149,000 in FY84) is now more than 40 percent. We believe that current AFLC procedures for computing SSD safety level requirements are causing those requirements to be understated and are a major contributing factor to the increase in outstanding SSD backorders. If these procedures are not changed and the trend of increasing backorders continues, the effect on aircraft availability rates is potentially greater than that associated with possible cuts in SSD funding.

We therefore recommend that the Air Force:

- Ignore the effect of SSD funding constraints on projected aircraft availability rates unless SSD funding cuts exceed 15 percent of requested peacetime OA or are imposed two or more years in succession.
- Review AFLC policy regarding wholesale safety levels for SSD materiel, with a view to raising SSD safety level requirements.

TABLE OF CONTENTS

1. SSD FUNDING AND AIRCRAFT AVAILABILITY RATES

BACKGROUND

The Systems Support Division (SSD) of the Air Force stock fund finances wholesale and retail supply levels for the roughly half-million consumable repair parts assigned to the Air Force for management within the Department of Defense supply system. Like all DoD stock funds, the Air Force stock fund is a revolving fund that pays for replenishment of its stocks with cash generated by sales to using customers.

In the case of the SSD, these customers are primarily the Air Force's industrially funded depot maintenance activities at its five Air Logistics Centers in the United States, and organizational and intermediate repair activities, funded by Operations and Maintenance appropriations, at Air Force bases in the United States and around the world. Air Force depots account for slightly more than 50 percent of the SSD's total annual sales, and repair activities at bases account for another 20 percent. The remaining 30 percent of sales are to other customers in DoD and elsewhere in the Government, the largest being the Navy and the U.S. Foreign Military Sales program.

SSD items serve primarily as repair parts for other, reparable components and subsystems that have been removed from aircraft and are undergoing depot-level or base-level repair. In this sense, SSD items for the most part play an indirect role in the support of aircraft.

Every year, in its annual budget submission, the Air Force requests Obligational Authority (OA) for the SSD and other divisions of the Air Force stock fund. When the budget year starts, a year later, the SSD and other divisions begin executing their programs. OA approved in the budgeting process (and in midyear reviews) is used throughout the year to place contracts with manufacturers and suppliers for required stocks. In this sense, OA approved in the budgeting and midyear review processes constitutes the "funding" for the SSD and other divisions of the Air Force stock fund. A "cut" in funding for the SSD occurs when approved OA is less than requested OA.

The total OA request in an SSD budget is made up of operating OA for replenishment and other peacetime requirements, OA for inventory augmentation, and OA for war reserve requirements. The operating portion of the total SSD OA request is consistently the largest portion of the SSD budget. Over 80 percent of the FY85 request, for example, was for operating OA. Operating OA is classically "stock-funded" (as opposed to "appropriated") in that it is subject to review, modification, and approval by the Comptroller and other offices within the Office of the Secretary of Defense (OSD) and by the Office of Management and Budget (OMB), but it does not require Congressional appropriations. The SSD is required to seek appropriations for the purchase of war reserve stocks and for the purchase of new or additional stocks (inventory augmentation) to support force growth and modernization, modification programs, and readiness improvements.

An important part of the stock fund concept, embedded in DoD policy for stock fund requirements and operations, is that, although stock-funded materiel is deemed important to support military repair and resupply operations, the nature of the materiel is supposedly such that military needs can be satisfactorily met by the financially oriented management mechanisms that characterize revolving funds. By design, the SSD operates in many respects more like a private-sector wholesaler and retailer in the business of selling goods to consumers than a logistics support organization focused on supporting military objectives. Though customer support is important and a key factor influencing day-to-day operations at Inventory Control Points, the prime objective in setting overall SSD requirements is to meet minimum safety level requirements, minimize costs, and live within budgetary and workload constraints, rather than to meet specific supply performance objectives driven by mission- or weapon-system-readiness criteria.

Accepting this concept for the items financed by the SSD, the Air Force nevertheless would like to be able to project the probable effects of different SSD funding levels on aircraft readiness rates. OA requests from the SSD have been growing in recent years, and, in both internal Air Force reviews as well as evaluations by OSD and OMB in the budget process, the amounts in question have typically been subject to downward adjustments. These pressures to reduce funding, coupled with

increasing emphasis on linking supply requirements to the readiness of weapon systems, underlie the Air Force's interest in the resources-to-readiness question for SSD budgets.

Our goal, then, is to estimate the probable effect of SSD funding on aircraft availability rates. Our results have implications for other issues facing the SSD and the Air Force stock fund, and their parent organization, the Air Force Logistics Command (AFLC). These issues include the modification of AFLC's methods for computing SSD stockage requirements, the movement to a weapon-system orientation for secondary-item management, and the question of stock-funding for depot-level reparables. We address these issues after presentation of the central results.

The data and analysis supporting all results are presented in the Appendix.

A DOLLARS-TO-AIRCRAFT RULE OF THUMB

Aircraft availability rates are not highly sensitive to normal SSD funding fluctuations. This is due to the largely indirect role SSD items play in the resupply system for supporting aircraft, combined with substantial management flexibility on the part of the SSD and AFLC to accommodate an SSD budget cut (mainly by temporarily reducing order quantities) without greatly hampering supply performance. This does not mean that current SSD budgets should necessarily be cut, nor that the SSD could manage its way through deep or repeated cuts over several years without having an adverse effect on aircraft availability rates. Such cuts would result in a *de facto* lowering of safety levels, which has the potential for greater and more permanent impact on aircraft availability rates than temporary reductions in order quantities. The relation between SSD safety levels and aircraft availability rates is discussed further below and is also the subject of [1].

As a rule of thumb, we estimate that for each $9 million in peacetime OA that is not approved in an SSD budget request, the average number of aircraft awaiting the repair of a part increases (a leadtime later) by at most one aircraft. This rule can be applied to a cut of up to $450 million between requested and approved OA, assuming order quantity reductions of up to 25 percent (worth $450 million) could be taken without a significant increase in order frequencies in the execution year. Taking the size of contemporary SSD budget requests for operating and inventory augmentation OA as representative (the FY85 request was for $2,800 million), a reduction of $450 million would

represent a cut in SSD OA of about 15 percent. A one-time 15-percent cut in SSD funding, therefore, increases the estimated average number of aircraft awaiting the repair of a part by no more than 50 airplanes over what it would have been otherwise. This is out of a total active Air Force, Air Force Reserve, and Air National Guard fleet of more than 7,500 aircraft, with an estimated average of at least 750 aircraft likely to be awaiting a serviceable component from supply or maintenance anyway (based on a maximum feasible fleet availability rate of 90 percent). Table 1-1 displays the potential effects of such a cut by weapon system. The effects of a cut smaller than $450 million can be estimated by linear interpolation of the results in the table. A cut in SSD OA of more than 15 percent could produce more serious effects on aircraft availability, because of greater sensitivity of availability rates to SSD safety levels.

These results are projections, not predictions, of supply performance. They are based on an analysis and model of the methods used by AFLC for computing requirements, financing, and managing SSD materiel; an important relationship between outstanding unit backorders for SSD items and the average awaiting parts (AWP) time for reparable components used on aircraft and aircraft engines; and aircraft availability projections obtained with the Aircraft Availability Model (AAM)[1], which can compute the effects on aircraft availability rates if depot and base repair times for reparables increase due to increased AWP times for SSD items.

The results are subject to several important qualifications. First, they were obtained without the use of application data showing which SSD items are used by which aircraft and their constituent reparable components. Second, the results assume that funding cuts are absorbed by adjustments in the requirements for demand-based replenishment materiel. Finally, there are important distinctions in both content and effect between the steps the SSD takes to achieve a temporary

[1]The AAM was developed for the Air Force by the Logistics Management Institute (LMI) and has been used for several years by the Air Staff [Headquarters, U.S. Air Force (HQ USAF)] to analyze the availability implications of programs and budgets for reparable components. The model is described in [2]. A version of the model is being incorporated by AFLC into its requirements calculation system for reparables (the D041 system).

TABLE 1-1. POTENTIAL AVAILABILITY EFFECTS OF A ONE-TIME CUT OF $450 MILLION IN SSD FUNDING

AIRCRAFT TYPES WITH TOTAL FY85 FLEET SIZES		NUMBER OF AIRCRAFT AT 75% AVAILABILITY	DROP IN AVAILABILITY (PERCENTAGE POINTS)	ADDITIONAL AIRCRAFT AWAITING REPAIR OF A PART
Attack				
A-7	325	244	0.5	1.5
A-10	583	437	0.7	4.5
A-37	106	80	0.5	0.5
	1,014	761		6.5
Bombers				
B-52	241	181	1.0	2.5
B-111	57	43	1.0	0.5
	298	224		3.0
Airlift				
C-5	65	49	0.7	0.5
C-130	696	522	0.5	4.0
C-135	701	526	0.5	3.5
C-141	254	191	1.0	2.5
	1,716	1,288		10.5
Fighters				
F-4	1,473	1,105	0.6	8.5
F-5	102	77	0.5	0.5
F-15	612	459	1.0	6.0
F-16	668	501	0.9	6.0
F-106	97	73	0.5	0.5
F-111	294	221	1.0	3.0
	3,246	2,436		24.5
Trainers				
T-33	144	108	0.3	0.5
T-38	803	602	0.7	5.5
T-39	103	77	0.5	0.5
	1,050	787		6.5
Helicopters				
H-1	126	95	0.4	0.5
H-3	75	56	0.6	0.5
H-53	42	32	0.0	0.0
	243	183		1.0

reduction in obligation outlays and the steps entailed if a permanent reduction in the cost of operating the supply system is to be achieved. These points are discussed in turn.

It is clear that in the real world, constraints on SSD obligations would ultimately affect different aircraft in different ways. To project these effects, however, would require complete and accurate application data for the half-million items in the SSD *and* specific information on which SSD items would be affected by the constraints. Neither kind of information is available in the detail required. Instead, we estimate the across-the-fleet effect of SSD funding on aircraft availability rates, taking application data for reparables into account with the AAM, but without specifying particular SSD applications. This is done by computing the increases in average SSD AWP time across all reparable items with nonzero base and depot repair pipelines (as recorded in a D041 data base for reparables) and spreading the increases uniformly across those pipelines. Table 1-1 breaks out the maximum effect of a $450 million cut in SSD funding by weapon system, but it does so on the basis of application data for reparables only, using the uniform spreading technique for SSD AWP time increases. Although this technique is not able to identify the particular aircraft types that would actually suffer more than others from an SSD funding cut, the technique does project the overall impact on the total force.

The second important qualification to the results is that they assume a cut in the computed, demand-based-replenishment, item-specific portion of an SSD budget request. An SSD budget is the result of a requirements determination process that has three stages: the item-specific calculation of gross level requirements by the Economic Order Quantity (EOQ) Requirements Computation System (D062), in which requirements for both demand-based and nondemand-based items are computed; the item-specific calculation of net requirements by the Central Secondary Item Stratification (CSIS) system, in which assets are applied to compute net from gross requirements; and a transition process, in which scrubs, error adjustments, and additives are incorporated to produce the final budget request. Requirements developed in the final, transition stage are not always item-specific, and they can be substantial. A good example is the Reorder Level (ROL) Deficit Additive requirement, which amounted to $474.3 million in the FY83 SSD budget request.

If funding cuts are absorbed by reduction in order quantities or level requirements for demand-based items, the effects on aircraft availability rates can be modeled. Such effects cannot be modeled if there are reductions in additive requirements, or if nondemand-based requirements, or specific inventory-augmentation programs, are reduced. Under the latter conditions, the effects depend entirely on what is reduced or eliminated.

If, for example, a cut is made and taken in a specific inventory augmentation program for a specific weapon system, the effects on that weapon system can presumably be estimated. If the cut is absorbed by reducing an additive added in transition, there may be no direct effect at all. In the case of the FY83 SSD budget, for example, when only $1.6 billion out of a requested $2.1 billion in OA was approved, there is evidence that the FY83 SSD ROL Deficit Additive requirement of $474.3 million was significantly overstated (by more than $500 million -- see [3]). If AFLC had been aware of this at the time, the projected effects of the FY83 $500 million "cut" in funding would have been essentially nil. AFLC was not aware of an overstatement, however, so guidance was issued to item managers to reduce order quantities to conserve obligations. Even with these actions, effects on aircraft availability rates were negligible. In fact, the Air Force's average, fleet-wide mission-capable (MC) rate actually improved from FY83 to FY84, indicating the FY83 SSD funding "cut" had virtually no effect on readiness. (Although aircraft MC rates have a broader meaning than aircraft availability rates, they are related measures of weapon-system readiness used by the Air Force.)

Finally, it is entirely possible that some funding cuts might be absorbed by eliminating or postponing various nondemand-based requirements. This would certainly occur if a funding cut were too large to absorb entirely through reductions in order quantities. Nondemand-based requirements are requirements computed or established by methods other than demand-based requirements models. They include stocks to support nonrecurring demand (e.g., scheduled overhauls or modification programs), insurance items, and various types of quantitative requirements of a nonrecurring nature. Nondemand-based requirements represent a substantial portion of the total SSD requirement each year (over $1,000 million out of the $2,800 million requested for FY85, for

example.) The effects on aircraft readiness of cuts in nondemand-based programs must be examined on a case basis; they cannot be modeled with traditional supply models.

OBLIGATION OUTLAYS AND SAVINGS

When approved OA is lower than requested, AFLC and the SSD must find a way to reduce obligations in the course of execution. As noted earlier, this is done primarily by reducing wholesale order quantities. These are the quantities that AFLC item managers order from manufacturers and suppliers when wholesale reorder points are reached. In FY83, for example, in response to the $500 million reduction in OA, AFLC instructed its item managers at the wholesale SSD Inventory Control Points (ICPs) to order only 58 to 90 percent of computed order quantities for items in a buy position. [The exact percentage depended on the management intensity categories for the items, whether the items were communications and electronics items or not, and the Logistic Support Priorities of the specific forces (airlift, strategic, tactical, etc.) served by the ICPs.]

We obtained the central results of the study by modeling the effect of such reductions in order quantities. If the average demand rate is stable or increasing, however, and measurements are taken over a period long enough to be unbiased by stochastic effects, reductions in order quantities lead to increased frequency of ordering, and obligation outlays will be unchanged. (In the long term, if all customer orders are eventually filled, obligations -- in terms of units ordered -- must equal demands.) There is, then, a question: How can reducing order quantities reduce obligations?

The answer lies in the year-to-year nature of the budget process. Since many SSD items have computed order quantities greater than or equal to a year's worth of demand, a one-time reduction in those quantities is likely to achieve a reduction in obligations *in that year*, even though obligations in the long term will be the same. This is particularly true if the reduction is moderate and is imposed in the latter part of the year. Under such conditions, though reorder points may be reached sooner, they are still not likely to be reached again during that year.

The dollar values in the rule-of-thumb results, therefore, represent the difference between the aggregate value of unreduced, baseline order quantities for SSD items and their aggregate value when reduced on a one-time basis. This difference measures the reduction in obligation outlays

achieved with a one-time reduction in order quantities, assuming reorder points are not reached again until after the year in question has ended. The $450 million figure in the results corresponds to an across-the-board cut of 25 percent in order quantities. (Note: Total baseline order quantities represent about $1,800 million in required OA; the remainder of the $2,800 million FY85 peacetime requirement represents nondemand-based requirements and additives.)

If constraints on obligations are so severe that order quantities are deeply cut (e.g., by more than 25 percent), the negative effects on availability rates may be increased. If reductions in order quantities are deep, reorder points can be reached again (perhaps more than once) within the period of constrained obligations. If OA is exhausted, item managers may find themselves unable to place orders, even though reorder points have been reached again, and a new constraint on operations has come into play. Reorder points are, in effect, forced down. This can lead to an increase in the number of outstanding backorders for SSD items and an increased likelihood that aircraft availability rates will suffer, beyond the effects of moderate reductions in order quantities. Permanent lowering of reorder points is equivalent to reducing level requirements, which is equivalent to reducing safety levels. The projected effect on fill rates, backorder levels, and aircraft availability rates of a reduction in SSD safety levels is the subject of an earlier LMI working note on the Air Force stock fund and aircraft availability [1]. That study shows that aircraft availability rates are more sensitive to SSD safety level reductions than they are to reductions in SSD order quantities, a conclusion verified in the current analysis. The system-wide model used in the present analysis shows that the average number of nonavailable aircraft increases by 5 to 6 airplanes for every $9 million taken out of SSD safety levels, as opposed to the increase of only 1 aircraft for every $9 million taken out of order quantities.

This argument includes an important point about the nature of AFLC's management flexibility in dealing with an SSD funding cut. AFLC can *postpone* obligations by cutting order quantities but cannot avoid them (assuming stable or increasing demand). This means that eventually obligations will have to be made to "make up" for any postponed obligations in a year when the budget is cut. Failure to "make up" the funds in future years (again, assuming stable or

increasing demand) can lead to the *de facto* lowering of reorder points described above. The result, as we have pointed out, can be a more serious reduction in aircraft availability rates than would result from simple reductions in order quantities. Thus, although a moderate, one-year cut in SSD funding can be managed without significant effect on aircraft availability rates, SSD funding cuts every year for several years would have more serious effects.

Assuming stable demand rates and leadtimes, true savings in SSD operations (as opposed to temporary reductions in obligations) can be achieved only by reductions in nondemand-based, additive-type programs, or reductions in level requirements at wholesale and retail supply points in the supply system, or both. Such reductions necessarily entail a reduction in the projected level of supply performance to be provided to customers. Of course, improvements in such areas as demand projection or modeling methods, or steps to shorten leadtimes or improve distribution, are other ways to achieve true savings, without causing reductions in customer support.

2. SSD SAFETY LEVELS AND AIRCRAFT AVAILABILITY RATES

The central goal of this study was to project the effects of different SSD funding levels on aircraft availability rates, and the main result is that the projected effects are relatively minor. This is not to say that there are no connections at all between SSD operations and aircraft availability rates -- only that funding variations are not likely to be the cause of availability problems. In fact, the relationship between SSD operations and aircraft availability rates is such that AFLC's present SSD safety level policy, rather than SSD funding, has the greater potential for causing undesirable availability effects.

Since 1975, AFLC has operated under the rule that the aggregate value of SSD safety levels at each ICP should be equal to the value of 55 days' worth of demand. Since FY81, however, wholesale SSD fill rates have fallen steadily, dropping more than seven points from the 87-percent level they reached in that year. More importantly, in terms of probable effects on aircraft availability rates, outstanding requisition backorders at the wholesale level for SSD items have been increasing steadily since FY80, rising from an average of about 104,000 in place at any given time in that year to an average of almost 149,000 in place during the first eight months of FY84 (a cumulative increase of more than 43 percent). And, although the FY83 funding cut certainly did not make things any better, this deterioration began *before* the SSD began to experience funding reductions. The OA approved in the budget process for the SSD for FY80, FY81, and FY82 was, respectively, 99, 100, and 100 percent of the requested OA for each of those years.

The 43-percent increase in average outstanding backorders from FY80 to FY84 translates (other things being equal) into a projected 43-percent increase in average SSD awaiting parts (AWP) time for reparable components in depot repair and an estimated 20-percent increase in average SSD AWP time for reparables in base repair. Spread uniformly across depot and base repair pipelines for reparables, these increases in AWP time produce a projected decrease in aircraft availability rates

corresponding to about 100 more aircraft awaiting the repair of a reparable component at any given time in FY84 than would have been the case if SSD backorders had not increased.

Unfortunately there are no supply or maintenance data available from Air Force reporting systems sensitive enough to show whether this increase in nonavailable aircraft actually took place between FY80 and FY84 (or whether other segments of the logistics system had to spend more, or work harder, to take up the SSD slack). It is true that the Air Force logistics community began to view AWP as a serious problem during this period. This concern was reflected in a briefing [4] by HQ Tactical Air Command on "The Impact on Combat Capability of Recoverables Awaiting Parts – AWP the #1 Spares Problem," presented at the Air Force Logistics Capability Symposium in March 1982.

We believe that AFLC's SSD safety level policy is a major contributing factor to the increase in SSD backorders and that outstanding SSD backorder levels will continue to rise if the policy is not changed. Under these circumstances, the potential effects on aircraft availability rates are serious enough to justify reevaluation of AFLC's SSD safety level policy. This is particularly true in light of an AFLC report [5] describing "unforecast increased demands" as the "leading" cause of outstanding backorders (responsible for roughly 40 percent of the "top 500 AFLC EOQ" backorders in place for the period June through December 1983).

The purpose of safety levels is to accommodate variations in demand. The 55-days'-worth-of-demand safety level policy (or any other safety level policy that is strictly demand-based) does not take into account the possibility that demand variability may be increasing, a view supported by the AFLC report. Nor does AFLC's present policy take into account increases in administrative and production leadtimes since the mid-1970's. These increases have caused pipelines to grow even faster than demand. Under these circumstances, the 55-days'-worth-of-demand safety level policy is not likely to have provided enough of the required growth in safety levels needed to hold supply performance constant. By maintaining its present policy, AFLC denies itself a useful tool for improving supply performance for SSD materiel. For these reasons, we believe a change in SSD safety level policy and increases in SSD safety level requirements are justified.

3. CONCLUSIONS AND RECOMMENDATIONS

SSD FUNDING AND AVAILABILITY

Due to the nature of SSD materiel, and the ability of AFLC and the SSD to postpone obligations by temporarily reducing order quantities, normal SSD funding fluctuations are likely to have only minor effects on aircraft availability rates. This is true for a moderate, one-time cut in SSD funding. Deep cuts in operating-level requirements or repeated cuts in the SSD budget over several years would affect availability rates more seriously.

Based on this conclusion we recommend that -- for purposes of aircraft availability and mission-capable rate projections -- the Air Staff ignore the potential effects of SSD funding fluctuations as negligible, unless SSD OA funding constraints exceed 15 percent of the total SSD replenishment request, or funding cuts are imposed two or more years in succession.

Inherent in the central conclusion of the study is the view that AFLC's *method of temporarily* reducing order quantities (as opposed to reducing level requirements) is the most reasonable way to execute an SSD budget that is below requested amounts. Reductions in customer support are minimized, and the delayed obligations have the *possibility* of becoming a permanent savings, if demand fails to materialize at projected levels.

SSD SAFETY LEVELS AND AVAILABILITY

For the SSD to achieve permanent savings (rather than reduce obligation outlays in a given year to conform to a budget cut), and to do this strictly with inventory, SSD safety level requirements would have to be reduced, or additive programs cut, or both. Projected supply support delivered to customers would suffer if this were done. As alternatives, savings can be achieved through improvements in other segments of the logistics system that are often taken for granted when supply requirements are computed. Improved demand projections and cost estimates, better methods for calculating requirements, and reductions in transportation times and procurement leadtimes can all yield savings in SSD operations without reducing supply levels or customer support.

Because of potential effects on availability, we think attempts to achieve savings by reducing SSD safety levels would be a mistake. In fact, a case can be made for increasing safety levels, based on trends in SSD supply performance since 1980 and potential effects on aircraft availability rates if these trends continue.

We therefore recommend that AFLC review its longstanding 55-days'-worth-of-demand policy for setting SSD safety levels and give serious consideration to raising SSD safety level requirements.

WEAPON-SYSTEM MANAGEMENT AND STOCK-FUNDING OF REPARABLES

Although the projected availability effects of an SSD funding cut are small and may therefore not be helpful in the defense of an SSD budget, the effects do tend to affirm the idea that requirements for consumable repair parts can be computed satisfactorily by AFLC and the SSD with traditional stock fund requirements models. That is, cost-minimizing EOQ models can continue to be applied to SSD materiel without hindering efforts to improve end-item readiness. This point is worth keeping in mind in overall evaluations of stock fund operations. In particular, it has implications for two other issues facing AFLC and the Air Force stock fund: the movement to a weapon-system orientation for secondary item management and the stock-funding of depot-level reparables.

The concept of weapon-system management is described in detail in a report [6] that was issued recently by the Supply Management Policy Group (SMPG). The SMPG is a joint Service, Defense Logistics Agency (DLA), and OSD working group assembled to address supply policy issues. The SMPG report describes the capabilities that the Services and DLA must develop to achieve a weapon-system orientation in the five basic areas of secondary item management: item identification, requirements determination, information systems, resource development and allocation (i.e., programming and budgeting), and materiel management (i.e., execution).

To the extent that the SSD is capable of computing requirements to meet military objectives satisfactorily, the need to develop a weapon-system orientation for SSD requirements is not as pressing as it may be in other areas of secondary item management (e.g., for reparable items, engines, and test equipment provisioning). Specifically, given the small effect that fluctuations in SSD budgets are projected to have on aircraft availability rates, we believe that a program to convert the

entire requirements determination process for SSD materiel (embodied in the D062 system -- a large-scale, AFLC-wide automated data and computation system) to a true weapon-system orientation, and in particular to develop accurate application and indenture files for the more than half-million SSD items, can be assigned a relatively low priority. This is not to say that development and execution of SSD budgets could not be improved through the development and use of application and indenture data for selected, high-management-intensity items. Recent work by Muckstadt and Sherbrooke [7, 8] indicates, for example, that a given amount of SSD OA funding can be used more efficiently (i.e., produce improved end-item availability for the same investment) if indenture relations between reparable components and consumable subassemblies are taken into account.

For these reasons, we conclude that Air Force moves to comply with the SMPG initiatives need not focus on consumable item management as a first priority. The existence of a rule of thumb for evaluating the potential weapon-system effects of SSD funding decisions (the results of this study), coupled with the fact that projected effects are relatively small, is enough to satisfy the basic thrust of the new weapon-system policy in the interim, while AFLC moves forward with the development of new management systems for secondary items [e.g., the Requirements Data Bank (RDB) project].

The second important issue facing the Air Force stock fund is the stock-funding of depot-level reparables. The implications of this study are not that the stock-funding of reparables is a good or bad idea, but rather that there are key differences between reparables and consumables in the way they affect aircraft, and that these differences should be recognized if reparables become stock-funded.

The reason the projected availability effects of an SSD funding cut are small is not that supply performance for SSD materiel is insensitive to SSD funding, but that aircraft availability rates are relatively insensitive to SSD supply performance. The analysis shows that a 50-percent reduction in SSD order quantities has the potential to increase outstanding wholesale SSD unit backorders by as much as 40 percent. This would represent a substantial decline in internal SSD supply performance. The analysis also shows, however, that even a 40-percent increase in SSD unit backorders results in less than a two-percentage-point drop in the projected, fleet-wide availability rate, which (although it

does equate to approximately 100 more nonavailable aircraft on average), is a relatively small effect in a fleet of more than 7,500 aircraft.

The fundamental reasons for this lack of sensitivity are that SSD items, for the most part, affect aircraft only through their effect on repair times for reparables, and that most of these repair effects are felt at depots rather than bases. In [1], for example, it is shown that only about 6 percent of the reparables entering base repair generate demand for SSD repair parts. The net effect is that aircraft are buffered from reacting strongly to fluctuations in SSD supply performance. This is not true for reparable components, which see heavier use at the flight line and in base repair and are much more likely to directly affect aircraft. (AAM projections, for example, show that the average number of aircraft awaiting a part increases by 3 to 8 aircraft for every $9 million taken out of recoverables funding, as opposed to the additonal 1 aircraft that becomes unavailable when SSD funding is cut and order quantities reduced by $9 million.)

For these reasons, we suggest that the Air Staff and AFLC ensure that weapon-system-oriented methods for computing reparable-item requirements are preserved if reparables are transferred into the Air Force stock fund for management.

We believe that unlike consumable repair parts, reparable components do not lend themselves to traditional EOQ inventory models for computing requirements. The effect of reparables on aircraft availability rates is greater and demands the use of weapon-system-oriented requirements models to ensure efficient use of resources. Note that this is *not* a recommendation against the stock-funding of reparables per se. For purposes of financial management and inventory control, the stock-funding of depot-level reparables may well be a good idea worthy of Air Force consideration.

APPENDIX

ANALYSIS

LINKING SSD FUNDING AND AVAILABILITY RATES

The steps involved in linking Systems Support Division (SSD) funding levels to aircraft availability rates are outlined below. They provide a simplified view of our basic approach. Each step is described later in greater detail. The data and arguments in [1] underlie key portions of the methods used in the analysis:

Step 1. An SSD funding cut occurs.

Step 2. The Air Force Logistics Command (AFLC) and the SSD react to the cut by reducing wholesale order quantities.

Step 3. Expected ordering frequencies increase, and, because reorder points have not changed, expected nonfill rates increase.

Step 4. The increase in expected nonfill rates is accompanied by an increase in the SSD wholesale expected backorder (EBO) level (the average number of outstanding, wholesale SSD backorders).

Step 5. The increase in projected SSD wholesale EBOs associated with a permanent reduction in order quantities serves as an upper bound on the increase in SSD EBOs described in *Step 4*.

Step 6. Average SSD awaiting parts (AWP) times for reparable components in depot and base repair increase by amounts determined by the percentage increase in SSD EBOs computed in *Step 5*.

Step 7. Increases in the size of depot and base repair pipelines (due to increases in average SSD AWP times) cause aircraft availability rates to fall.

The analysis assumes fixed leadtimes and steady-state conditions for demand. By steady-state demand we mean that the characteristics of the underlying demand distribution (e.g., mean and variance) do not change over time. Although actual, real-world demand for SSD materiel may or may not be steady-state, the steady-state assumption is standard for an analysis of this type, where funding is the control variable and demand is taken as a given.

DETAILED DESCRIPTION OF STEPS

Step 1. An SSD funding cut occurs.

In the course of a budget or midyear review, the Obligational Authority (OA) approved for the SSD is lower than the amount requested. This means that in executing its programs, the SSD must obligate less than it had planned. (The SSD, like other stock fund operations, obligates funds when it enters into contracts with its suppliers, and pays out cash when it receives the materiel a leadtime later.)

Step 2. AFLC and the SSD react to the cut by reducing wholesale order quantities.

AFLC and the SSD do not have formal procedures in place to deal with a funding cut. As a result, when approved OA is less than requested, they have the flexibility to react in different ways.

In response to the FY83 funding cut, a set of FY83 buy guidelines were issued to the Inventory Control Points (ICPs) in the form of reduction percentages for order quantities, to be applied when reorder points were reached and orders were placed. These reductions were based on customer Logistics Support Priorities and the nature of the items affected (e.g., communications and electronics items received special guidance). This was done with the idea of minimizing the impact on key customers and weapon systems. In addition to the order quantity reductions, AFLC also set aside contingency funds for discretionary use while the buy guidelines were in effect, discontinued quantity discount and expanded buy programs, and issued guidance to the ICPs to issue to zero assets and buy only demand for nonmission-essential items. Reorder points were not lowered.

Step 3. Expected ordering frequencies increase, and, because reorder points have not changed, expected nonfill rates increase.

No change is made in reorder points in response to the funding cut -- only order quantities are reduced. The result is that expected ordering frequencies increase and expected nonfill rates rise. The term "expected" is used in the following sense: If observed for a fixed period of time -- say, a year -- the number of orders placed for an item is the ordering frequency for the item for that year. Since demand is stochastic, this annual ordering frequency is a random variable that can change from

year to year. The expected ordering frequency is the average value of this random variable. Similarly, the expected nonfill rate for an item is the average value of the annual nonfill rate, viewed as a random variable that can take on different values from year to year.

A reduction in order quantities, even if temporary, increases expected ordering frequencies by some amount. Since reorder points have not changed, the increase in expected ordering frequencies implies an increase in expected nonfill rates. Reorder points represent the level of protection against the occurrence of backorders. The more often they are reached, the more often backorders will occur on average, and this is what is meant by an increase in expected nonfill rates.

> *Step 4. The increase in expected nonfill rates is accompanied by an increase in the SSD wholesale EBO level (the average number of outstanding, wholesale SSD backorders).*

An increase in expected nonfill rates causes the SSD EBO level to increase. This follows from the fundamental relationship:

$$\text{EBO} = \text{AD} \times \text{NFR} \times \text{AVBOD},$$

where AD = average demand, NFR = expected nonfill rate, and AVBOD = the average duration of a backorder. This relation, which applies equally well to one item or to averages over a collection of items, holds for any steady-state inventory system. (Note: The value of AVBOD does not depend on order quantity size. It depends only on reorder points and procurement leadtimes, neither of which changes in this analysis. Thus the percentage increase in wholesale SSD EBOs is equal to whatever the percentage increase is in the system-wide SSD expected nonfill rate, when order quantities are reduced.)

> *Step 5. The increase in projected SSD wholesale EBOs associated with a permanent reduction in order quantities serves as an upper bound on the increase in SSD EBOs described in Step 4.*

From *Step 4*, we know that the percentage increase in SSD EBOs is equal to the increase in NFR, the system-wide nonfill rate. To compute these increases, therefore, we need an inventory

model that can compute nonfill rates and EBO levels as a function of order quantities and reorder points.

An appropriate model is one similar to the D062 model that AFLC uses to compute SSD requirements in the first place. We would also like the model to yield a reasonable projection of real-world SSD wholesale supply performance (when order quantities and reorder points are set according to current D062 policy), so that projected effects have some credibility.

To meet these requirements, a D062 "emulator" was constructed. The emulator runs on a personal computer and uses a cost-and-demand data base for roughly 205,000 items out of the 500,000-plus items managed by the SSD. These 205,000 items are SSD items that experienced some level of recurring demand in the year that ended in March 1984. The data base was constructed from a March 1984 D062 management report (A-D062-002-H3-MMB). It consists of a 32 x 10 matrix, or template, of (unit cost)-by-(annual demand) cells, each cell containing the number of SSD items in the cost-and-demand category defined by the cell. (The complete data base for the emulator appears later in Table A-1.)

The emulator was constructed to have as many special characteristics of the production D062 model as possible (with one important exception), so that it would approximate what the D062 model itself would project as the results of a reduction in order quantities. The exception involves values used for standard deviations in leadtime demands. Standard deviations were chosen so that the emulator projected real-world wholesale supply performance levels (system fill rate and average outstanding backorders), given existing AFLC policy for D062 order quantities and reorder points. The study results, that 100 additional aircraft on average would be awaiting a part from maintenance if order quantities were cut by 50 percent, varied by fewer than 10 aircraft in either direction in response to changes of plus and minus 10 percent in standard deviations in leadtime demand. (The emulator could not be calibrated to project current SSD wholesale supply performance given AFLC-provided data on standard deviations in leadtime demand. In any case, use of the AFLC-provided data indicated even *less* sensitivity of aircraft availability to SSD funding than is projected with the "calibrated" emulator.)

Aside from the data and settings used in the emulator, there is another complication, which explains in part why the results of the study are upper bounds on the potential effects of an SSD funding cut, rather than point-wise projections. Both the D062 model and the emulator are analytic, steady-state, expected-value-type inventory models; that is, they calculate expected values for various measures of supply performance (e.g., EBOs) based on values for mean demand, order quantities, and reorder points that, once established, are assumed to be fixed in time. Such models, by their nature, cannot compute the transient effects of temporary adjustments in the inventory system, such as temporary reductions in order quantities.

Because the object is to reduce obligation outlays in the year in question, the order quantity reductions that AFLC and the SSD make in response to a budget cut are temporary, and, as we have said, the effects of such temporary reductions cannot be calculated exactly with steady-state models. Such models can, however, compute bounds on these effects. In particular, thinking of the steady-state reduction of order quantities as the limit of successively longer temporary reductions, it follows that the increase in the system-wide expected nonfill rate when wholesale order quantities are temporarily reduced is bounded above by the increase in the system nonfill rate when order quantities are permanently reduced (in the steady-state sense) by the same amount. The D062 emulator allows us to calculate these bounding increases in the steady-state EBO level both ways, either by examining the increase in NFR, or by looking at EBO levels directly. It is because the steady state effects are still relatively small that this bounding method provides useful results.

To compute the percentage increase in SSD EBOs resulting from a reduction in order quantities, we need a baseline EBO level against which to measure. To establish this baseline, the D062 emulator was set so that both safety levels and order quantities were consistent with existing AFLC/SSD policy under "full funding" (e.g., order quantities of no less than a year's worth of demand and safety levels with aggregate value equal to that of 55 days' worth of demand). With these settings, the emulator computes a projected wholesale EBO level for the SSD comparable to current (FY84) average outstanding backorders. (Further details on the baseline configuration of the

emulator are given later.) The excursion is then to reduce order quantities, leaving other settings the same, and see how the projected EBO level changes.

> *Step 6. Average SSD AWP times for reparable components in depot and base repair increase by amounts determined by the percentage increase in SSD EBOs computed in Step 5.*

This is the step that links SSD supply performance to quantities that have a direct effect on aircraft availability rates, namely, depot and base repair pipelines for reparables. The computational link is made possible by a useful and important relationship between EBO levels and average AWP times: The relative increase in average SSD AWP time (i.e., mean supply response time) in a repair process (at a depot or at a base) is equal to the relative increase in the average number of outstanding SSD backorders (EBOs) experienced by the repair process in its interaction with supply. In other words, as the average number of outstanding backorders for repair parts increases, so does the mean supply response time across all items in repair. An argument for this relationship appears in [1].

The emulator projects a 40-percent increase in wholesale SSD EBOs when order quantities are reduced by 50 percent across the board. (Such order quantity reductions have a value of approximately $900 million.) As shown in [1], a 40-percent increase in wholesale SSD EBOs results in an estimated 40-percent increase in average SSD AWP time for reparables in depot repair and an estimated 22-percent (worst-case) increase in average SSD AWP time for reparables in base repair. From the results in [1], the estimated effects on depot- and base-level average SSD AWP times are increases of 0.75 to 1.9 days at the depots and 0.11 to 0.14 days at the bases.

These values are the projected increases in average AWP times, where averages are taken over the entire set of reparables with nonzero depot repair pipelines and nonzero base repair pipelines, respectively. The particular values of these increases, of course, depend on the baseline (i.e., current) values for average SSD AWP times at depots and bases. These baseline values are derived in [1] from data drawn from wholesale and retail supply performance reporting systems in the Air Force.

Step 7. Increases in the size of depot and base repair pipelines (due to increases in average SSD AWP times) cause aircraft availability rates to fall.

The availability results corresponding to a $450 million funding cut for the SSD are based on the top ends of the interval estimates for increases in depot and base SSD AWP times. Those values, 1.9 days and 0.14 days, respectively (based on a $900 million, 50-percent reduction in order quantities), were halved to project the effects of a $450 million, 25-percent reduction in order quantities. The reason the maximum SSD funding cut addressed by this study is $450 million is that a funding cut greater than that would require reductions in order quantities greater than 25 percent (thereby running a serious risk of *de facto* lowering of reorder points) and would almost certainly provoke other management responses (described earlier) that must be considered on a case basis.

To compute availability effects, the Aircraft Availability Model (AAM) was run twice: once with *no* change in depot and base repair pipelines for D041 reparables, and once with those pipelines increased by 0.95 days and 0.07 days, respectively. A level of 75-percent availability across the board for the entire Air Force was chosen as a reasonable baseline against which to compare changes. This level of availability corresponds roughly to current levels of Air Force investment in reparable spares. The availability effects of an SSD funding cut can then be observed by comparison of availability rates, weapon system by weapon system, at equal (baseline) levels of investment in reparables.

D062 DATA AND EMULATOR

The Input Data

SSD demand and cost data used in this analysis were extracted from the data displayed in Table A-1. The data in the table are taken from two March 1984 D062 management reports: *Summary Analysis of EOQ Items – Part I Noncumulative* (A-D062-002-H3-MMB) and *Frequency of Demands* (A-D062-001-H3-MMB). SSD unit costs and annual unit demands were derived from the first report, and average requisition sizes (i.e., average units per requisition) by unit cost category were derived from the second report.

TABLE A-1. THE SSD EMULATOR DATA BASE

TOTAL DOLLAR VALUE OF ANNUAL DEMAND RANGE ($)		UNIT COST RANGE ($) 0–1	1–5	5–10	10–25	25–50	50–100	100–250	250–500	500–1000	1000–2500	TOTAL ITEMS	TOTAL ($000)
	0	9985	25260	20101	33830	30107	32778	42214	25324	17018	18853	255370.	
0	25	4790	7623	3113	2348.	0	0	0	0	0.	0	17874.	
		31	81	43	42	0	0	.0	0	0	0.		177
25	100	1428	4886	4307	6641	5337	2295	0.	0.	0.	0	24884.	
		75	261	231	382	326	166	0	0	0	0		1440
100	500	1407	4800	4020	8540	6408	9260	9179	2259.	0.	0	47865.	
		337	1159	953	2059	2097	2396	2658	803	0.	0.		12461
500	1000	481	1604	1424	3031	3137	3944	5497	3642	1781.	0.	24541.	
		339	1139	1018	2172	2238.	2823	3975.	2747	1250	0.		17703.
1000	2500	478	1524	1432	3059	3611	4495	6900	4613	3603.	1792.	31507.	
		765	2431	2283.	4888	5773.	7258.	11150	7639	6012.	3088.		51285.
2500	5000	207	768	676	1667	2140	2826	4496	3372.	2985.	2717	21854	
		746	2729	2373	5942	7601	10147	16187	12122.	10745.	10011.		78684.
5000	10000	117	380	343	871	1158	1671	2857.	2339	1953.	2513.	14202.	
		843	2620	2358	6034	7987	11479	19908	16400.	13744.	18034.		99408.
10000	15000	45	129	130	273	393	632.	1084.	1030	890.	1334.	5940.	
		547	1586	1576	3375	4787	7799	13193.	12534.	10942.	16406		72646
15000	20000	20	73	59	148	215	348	665.	595	555	873	3551.	
		348	1281	1030	2565	3726	6022	11502	10293	9590	15088.		61445.
20000	25000	6	53	29	87	134	202	437	417.	406.	613.	2384.	
		136	1162	660	1937	2972	4504	9726.	9345.	9058	13731.		53230.
25000	30000	9	16	28	59	86	148	294	300	276.	461.	1669	
		245	441	776	1622	2384	3820	7998.	8212.	7550	12662.		45710.
30000	35000	7	21	13	42	60	88.	229.	213.	212.	365	1242.	
		230	689	418	1358	1930	2585.	7423.	6926.	6839.	11827.		40224.
35000	40000	9	16	17	40	47	76	157.	158.	177.	314.	1011.	
		341	601	637	1496	1758	2874.	5875.	5921.	6621.	11778.		37902.
40000	45000	4	13	8	15	41	49	120	150.	120.	269.	789	
		169	545	335	638.	1748.	2093.	5085.	6331.	5103.	11390.		33437
45000	50000	1	8	12	14	27	46	126.	106.	117	205.	662.	
		46	376	578	659	1275	2174	5969	5029.	5559.	9719		31382.
50000	60000	4	16	15	32	42	62	158.	172.	219.	312	1032.	
		211	887	812	1755	2323	3403.	8494.	9427	11926.	17024.		56462
60000	70000	3	8.	6	28	40	38.	117	121.	122.	256.	739	
		195	508	382.	1798	2602.	2444.	7578.	7792.	7938.	16597.		47836.
70000	80000	0	6.	8	12	24	32	77.	86.	79.	183.	507	
		0	455	602	884.	1782	2401	5760.	6405	5909	13722		37920
80000	90000	1	7	7	11	21.	34	47	69	65.	133.	395.	
		82.	594	590	938	1783.	2898	3994.	5876.	5497	11276.		33529
90000	100000	0.	5.	2	7	16	19	56.	51.	73.	122.	351	
		0.	480	182	666	1522.	1788	5294	4814.	6920	11585.		33242.
100000	125000	1	7	11	14	35	39	91.	98.	96.	218.	610.	
		110.	795	1238.	1512.	3949	4302	10094.	10978	10674	24459.		68113
125000	150000	0	3	4	8	30	30.	68	54	83	144.	424.	
		0	415	534	1119	4229	4078	9208.	7413.	11370.	19422		57979
150000	175000	0	1	2	8	15	17	42.	29	49.	108	271.	
		0	157	339	1280	2396	2775	6794.	4703.	7973	17586.		44002
175000	200000	1	3	3	4	13	16.	34.	40.	27	83	224	
		184	565	545	737	2438	3009	6299	7424	5058	15427		41682
200000	300000	0	2	2	7	28	46	54.	65	77	206.	487	
		0	470	443	1891	6717	11246	13282.	15521	18441	50619		118632
300000	500000	0	0	5	12	23	22	57	26	45	141	331	
		0	0	2246	4677	8777	8635.	21230	9746	17784	53810.		126905
500000	750000	1	0	3	11	5	18	22	11.	13.	72.	156.	
		672	0	1907	7356	3352	10554	13136.	6328	8249	43571.		95124.
750000	1000000	0	0	0	9.	7	6	11	4.	6.	38	830	
		0	0	0	7682	5745.	5116.	9834.	5423	4744.	33168		71713
1000000	1250000	0	1.	0	2	0	4	5.	7.	6.	25.	50.	
		0	1091	0	2198	0.	4534.	5682.	7993	6492	27692.		55682.
1250000	1500000	0	0	0	7	3	1	3	2.	1.	13.	30.	
		0	0.	0	10011	3794.	1297	4008.	2730.	1428.	17741		41009
1500000	2000000	0	0	0	0.	2.	3	5.	4.	1.	7	22.	
		0	0	0	0.	3339	5347.	8325	6822.	1522.	12304		37659
2000000	5139125	0	0	0.	0	1	2.	9	9	6	8	35	
		0	0	0	0	2485	4519	31993	33326.	29754	41113.		143390
AVERAGE REQUISITION SIZE BY UNIT COST CATEGORY		119	32.	15	10	8	6	5.	3	3	2.		

The average unit cost for a typical item in one of the 320 cells in the central part of Table A-1 can be computed by dividing the total dollar value of the annual demand for all the items in the cell by the number of items in the cell. The total dollar value of annual demand for a typical item in a cell can then be estimated from the range on the left, based on the position of the unit cost estimate within the unit cost range. The average annual unit demand for a typical item in each cell is then given by dividing average annual demand by unit cost.

<u>The D062 Emulator</u>

AFLC computes requirements for SSD materiel with the Economic Order Quantity (EOQ) Buy Budget Computation System (D062) [9]. Within the D062 system, order quantities and safety levels for SSD items with recurring demand are computed with an inventory model (the D062 model) designed in compliance with Department of Defense guidance for computing wholesale supply requirements for nonreparable (i.e., consumable and field-level-reparable) secondary items [10]. The D062 model is essentially the model proposed by Presutti and Trepp in [11].

The D062 emulator used in this study has many of the characteristics of the D062 model. Like the D062 model, the emulator is a variable safety level model that computes order quantities and reorder points to minimize total system annual ordering and holding costs, subject to a constraint on the average number of system-wide outstanding wholesale backorders. The average number of outstanding wholesale backorders is also referred to as the average number of time-weighted requisitions short, and (in this report) as the SSD wholesale EBO level.

The "system" of items processed by the emulator consists of the 320 representative items defined by the cells in the input data base. In its processing, the emulator takes into account the number of items per cell. By taking cell multiplicities into account, the emulator in effect computes system values and performance levels for 205,000 SSD items.

A listing of the source code for the emulator is given at the end of this appendix. The emulator is programmed in FORTRAN77 (Microsoft, Version 3.2) and runs on an IBM or IBM-compatible personal computer with a Disk Operating System (DOS), Version 2.0 or higher.

Like the D062 model, the emulator assumes a Laplace distribution for demands in a procurement leadtime. Other special features of the emulator, similar to features in the D062 model, are as follows:

The ordering cost at an Inventory Control Point for an SSD item is set at $600. [This reflects a recent (1985) increase in ordering costs in the D062 model.]

The holding cost percentage for wholesale SSD items is 20 percent (applied to unit costs).

Procurement leadtimes (PLTs -- the sum of administrative and production leadtimes) are set based on averages by System Management Grouping Code (SMGC). The SMGC for an SSD item is a function of its dollar value of annual demand and determines the level of management attention paid to the item. Low management-intensity items (SMGC T) are the items reflected in rows 1 through 6 in Table A-1, medium-intensity (SMGC P) in rows 7 through 15, and high-intensity (SMGC M) in rows 16 through 32. In the emulator processing, PLTs are set based on AFLC-supplied data on average PLTs by SMGC (as of December 1984): 323 days for SMGC T items, 449 days for SMGC P items, and 559 days for SMGC M items.

The emulator computes order quantities as simple Wilson lot sizes, subject to the D062 constraints that order quantities shall be a minimum of 1-year's demand and no more than 3-years' demand. For analyzing the effects of reduced order quantities, the 1-year minimum constraint is relaxed.

The emulator computes safety levels based on an implied shortage cost (LAMBDA), which depends on a user-supplied constraint (BETA) on the SSD system-wide, wholesale EBO level. In line with D062 policy, safety levels are constrained to be a minimum of zero and maximum of the lesser of leadtime demand and three standard deviations of leadtime demand. In line with recent changes in D062 policy, the square root of unit cost (rather than unit cost) is used in computing the safety level factor (K). Also, to approximate D062 adjustments to safety levels based on item essentialities, average requisition sizes by unit cost categories are employed as described in [9] as surrogate factors for item essentiality. The baseline value for BETA is set so that the aggregate value

of safety levels is equal to the aggregate value of 55 days' worth of demand (the current AFLC policy for SSD safety levels).

The emulator allows the user to set different values by cell for the standard deviation in leadtime demand (SIGMA). The method is to compute a simple weighted average of three different possible values for standard deviation in leadtime demand: SIGMA1, based on a formula of Sherbrooke [12]; SIGMA2, equal to demand in a leadtime; and SIGMA3, based on average standard deviation in leadtime demand by SMGC (AFLC-provided data). A user-chosen multiplication factor for SIGMA (SIGFAC) may also be applied to examine the sensitivity of emulator results to values for SIGMA.

The baseline setting for the emulator is with a SIGFAC of 1.0 and weights of 1.0 and 2.0 for SIGMA1 and SIGMA2, respectively, and a weight of 0.0 for SIGMA3. (The emulator could not be calibrated to give realistic projections of SSD supply performance using the AFLC-provided values for SIGMA3. In any case, use of SIGMA3 values led to even less sensitivity of aircraft availability rates to SSD funding than that present in the final study results.)

With the baseline SIGMA values described above, and a baseline BETA constraint of 9,012,000 wholesale SSD unit backorders, the emulator projects a system-wide SSD wholesale gross fill rate of 85.8 percent and an average of 2,165,911 outstanding *unit* backorders (EBOs). (With the limits placed on upper and lower values for safety levels and order quantities in the D062 model, the BETA value ceases to function as an active constraint in the underlying constrained minimization problem. Instead, BETA becomes a purely technical "control knob" for adjusting safety levels, without a practical, real-world interpretation.)

The projected system fill rate of 85.8 percent and the projected unit EBO level of 2,165,911 are both in line with current, real-world SSD wholesale supply performance. The 85.8 percent fill rate is slightly higher than FY84 wholesale SSD fill rates (in the upper 70s and low 80s), but is the approximate fill-rate goal established by AFLC for the system. The system-wide average of 2.1 million *unit* backorders in place at any given time is consistent in order of magnitude with the current, real-world level of about 150,000 SSD wholesale *requisition* backorders in place at

any given time. This is because the average number of units per SSD wholesale requisition lies between 119 and 2 (based on D062 frequency-of-demand data by item unit cost category), and 2,165,911 divided by 150,000 falls into that range.

In the excursion with reduced order quantities (Qs), reduced Qs were used only in computing expected backorders and fill rates. The change in order quantities was not allowed to influence safety levels, which stayed at their baseline (55-days'-worth-of-demand) levels. With a Q reduction factor of 50 percent, the projected system fill rate went from 85.8 percent to 80.4 percent, and system unit EBOs increased 41 percent from 2,165,911 to 3,063,784. [Note that the 38-percent increase in the *nonfill* rate, from 14.2 percent to 19.6 percent, is comparable to the 41-percent increase in the EBO level, as predicted by the (EBO = AD x NFR x AVBOD) formula described earlier.]

The emulator can be easily modified to experiment with different policies for SSD safety levels and order quantities, and to examine the effects of other changes in the system (e.g., different leadtimes and different levels of variance in demand). As currently programmed, the model also gives the user the choices of using strict Wilson lot sizes for Qs, zero safety levels for all items, and the option of not using requisition sizes to adjust safety level calculations.

In addition to giving the values of input parameters and overall system-wide performance characteristics, the output report produced by the emulator displays the following information for each of the 320 cells in the input data base:

- Number of items per cell (MULTIPLICITY)
- Unit cost (C)
- Annual demand (D)
- Order quantity (Q)
- Procurement cycle (Q/D)
- Reorder point [R = leadtime demand + K(sigma)]
- Item fill rate (FR)
- Variance-to-mean ratio (VTMR = variance/leadtime demand)
- Unit expected backorders (EBO)

- Safety level factor (K)
- Value in dollars of 55 days of demand (V55DD)
- Item safety level in days of demand (VKID)
- Standard deviation in leadtime demand (SIGMA).

<u>Source Listing</u>

The following is a listing of the source code for the D062 emulator. The model is programmed in FORTRAN77 (Microsoft Version 3.2) and runs on an IBM or IBM-compatible personal computer operating with a DOS, Version 2.0 or higher. The model operates on input data of the type shown in Table A-1.

FORTRAN SOURCE CODE LISTING

```
C                   USAF SYSTEMS SUPPORT DIVISION (SSD)
C
C                       STOCK FUND MODELING TOOL
C
C
C
C     THIS MODEL WAS DEVELOPED SO THAT FROM THE INPUT OF VARIOUS LINE
C     ITEMS IN TERMS OF UNIT COST AND TOTAL ANNUAL DOLLAR VALUE OF
C     DEMAND, THE FOLLOWING VARIABLES COULD BE CALCULATED WITHIN A GIVEN
C     SYSTEM-WIDE BACKORDER CONSTRAINT:  ORDER QUANTITY (Q),  THE SAFETY
C     LEVEL FACTOR (K), THE ESTIMATED NUMBER OF BACKORDERS IN PLACE FOR
C     A COMPONENT (EBO), THE FILL RATE (FR), THE NON-FILL RATE (NFR),
C     THE SYSTEM WIDE FILL RATE (SWFR), THE REORDER QUANTITY (R), AND
C     THE AVERAGE TOTAL NUMBER OF BACKORDERS IN PLACE AT ANY TIME
C     (TEBOM).  THE MODEL USES THE LAPLACE PDF FOR DEMAND IN A LEADTIME,
C     BASED ON THE WORK OF PRESUTTI AND TREPP IN THEIR JUNE 1970 PAPER
C     IN THE NAVAL RESEARCH LOGISTICS QUARTERLY: "MORE ADO ABOUT EOQ".
C
C
C                         THE VARIABLES
C                         -------------
C
C     NAME     TYPE  DIMENSION  DESCRIPTION
C     ------   ----  ---------  -----------
C     OCCUR     R     (10,32)  OCCURANCES OF A CERTAIN DOLLAR DEMAND
C                              WITHIN A GIVEN PRICE RANGE
C     CELVAL    R     (10,32)  TOTAL ANNUAL ($000) FOR ITEMS IN CELL
C     UCOST     R     (10,2)   ITEM UNIT COST RANGE (LOW END, HIGH)
C     TADVD     R     (2,32)   TOTAL ANNUAL DOLLAR VALUE OF DEMAND
C                              RANGE (LOW END, HIGH)
C     TITEMS    R     (32)     TOTAL NUMBER OF ITEMS WITHIN A TADVD
C     TDOLAR    R     (32)     TOTAL ($000) VALUE WITHIN A GIVEN TADVD
C     D         R     (10,32)  AVERAGE ANNUAL DEMAND WITHIN EACH OCCUR
C     TD        R     (10,32)  SAME AS D IMMEDIATELY ABOVE
C     U         R     (10,32)  AVERAGE DEMAND IN A PROCUREMENT LEADTIME
C     EBO       R     (10,32)  AVERAGE NUMBER OF BACKORDERS IN PLACE
C                              FOR EACH OCCUR
C     C         R     (10,32)  AVERAGE UNIT COST FOR EACH CELL
C     Q         R     (10,32)  ORDER QUANTITY
C     FACQ      R     (10,32)  REDUCED Q
C     QRF       R              Q REDUCTION FACTOR
C     QDU       R     (10,32)  RATIO OF Q / D
C     K         R     (10,32)  SAFETY LEVEL
C     FR        R     (10,32)  THE FILL RATE
C     NFR       R     (10,32)  THE NON-FILL RATE
C     R         R     (10,32)  THE REORDER QUANTITY
C     RS        R     (10)     AVERAGE REQUISITION SIZE BY UNIT COST
C     V55DD     R     (10,32)  THE DOLLAR VALUE OF 55 DAYS OF DEMAND
C     DVK       R     (10,32)  THE DOLLAR VALUE OF THE SAFETY LEVEL
C     SIGMA     R     (10,32)  THE STANDARD DEVIATION OF UNIT DEMAND
C                              IN A PROCUREMENT LEADTIME
C     SIGMA1    R              SHERBROOKE FORMULA FOR SIGMA
C     SIGMA2    R              SIGMA = DMD IN PLT (i.e., U(I,J) )
```

1

```
C       SIGMA3     R                 AVG SIGMA BY SMGC FROM AFLC D062 DATA
C       VMRAT      R                 VARIANCE-TO-MEAN RATIO USED IN
C                                    COMPUTING SIGMA1
C       VTMR       R       (10,32)   CELL VARIANCE-TO-MEAN RATIO FROM SIGMA
C       W1,W2,W3   I                 WEIGHTS FOR AVERAGING SIGMA1,2,&3
C       SIGFAC     R                 FACTOR TO ADJUST SIGMA FOR
C                                    SENSITIVITY ANALYSIS
C       TEBOM      R                 TOTAL NUMBER OF BACKORDERS IN PLACE
C                                    AT ANY TIME
C       SWFR       R                 THE SYSTEM WIDE FILL RATE
C       FRCOST     R                 USED IN CALCULATING SWFR
C       UCSTWT     R                 USED IN CALCULATING SWFR
C       AVGDPU     R                 AVERAGE DOLLARS SPENT ON ONE UNIT
C       BETA       R                 THE SYSTEM WIDE BACKORDER CONSTRAINT
C       WLSQ       R                 THE WILSON LOT SIZE ORDER QUANTITY
C                                    ( A TEMP VARIABLE USED TO CALCULATE Q)
C       TV55DD     R                 SUM OF V55DD * MULTIPLICITIES
C       TVQR       R                 VALUE OF SAVINGS FROM Q REDUCTION
C       LAMBDA     R                 ACTUALLY NEGATIVE LAMBDA
C       COMPLX     R                 TEMPORARY VARIABLE
C       PART       R                 TEMPORARY VARIABLE
C       TSL        R                 TOTAL SAFETY LEVEL IN DAYS OF DEMAND
C       OC         R                 ORDERING COST ($600)
C       HC         R                 HOLDING COST (20%)
C       VKID       R       (10,32)   VALUE OF SAFETY LEVEL IN DAYS OF DEMAND
C                                    FOR TYPICAL ITEM IN COST-DEMAND CELL
C       SMALL      R                 TEMP. STORAGE FOR THE MINIMUM OF U(I,J)
C                                    OR 3*SIGMA(I,J).
C       FNAME      C*12              THE FILE NAME OF THE INPUT FILE
C       SAFLVL     C*1               Y FOR SAFETY LVLS, N FOR ZERO SAFETY LVLS
C       WLSNQ      C*1               Y FOR WILSON Q'S EXCLUSIVELY, N FOR
C                                    CONSTRAINED Q'S
C       ARS        C*1               Y FOR AVG REQ SIZE ENGLISH, N FOR RS=1
C       OARS       R                 OVERALL AVG REQ SIZE
C
C      ---------------------- DECLARATIONS ----------------------------
C
        REAL    OCCUR (10,32), UCOST (10,2), TADVD (2,32), TITEMS(32),
     *          TDOLAR(32), U (10,32), C (10,32), K (10,32), FR (10,32),
     *          NFR (10,32), D(10,32), R(10,32), Q (10,32), EBO (10,32),
     *          V55DD (10,32), DVK (10,32), QDU (10,32), VTMR(10,32),
     *          SIGMA(10,32), TEBOM, SWFR, FRCOST, UCSTWT, AVGDPU,
     *          BETA, WLSQ, LAMBDA, COMPLX, PART, OC, HC, TSL, RS(10),
     *          TV55DD, SIGFAC, CELVAL(10,32), VKID(10,32), TD(10,32),
     *          FACQ(10,32),QRF,TVQR,SMALL,OARS,SIGMA1,SIGMA2,SIGMA3
C
        CHARACTER FNAME*12, SAFLVL*1, WLSNQ*1, ARS*1
C
        INTEGER W1*4, W2*4, W3*4
C      -------------------------------------------------------------
C
C       READ IN FROM A SINGLE DATA FILE OCCUR,CELVAL,UCOST, TADVD, TITEMS,
C
        WRITE(*,10)
```

2

```
   10  FORMAT (' A STOCK FUND PROGRAM  - ',
     *        //' ENTER THE NAME OF THE INPUT DATA FILE TO BE USED.')
C
       READ(*,20) FNAME
   20  FORMAT (A)
C
       OPEN(1,FILE=FNAME)
C
       DO 300 J=1,32
       READ (1,30,END=900) (OCCUR(I,J),I=1,10)
  300  CONTINUE
C
   30  FORMAT (10F9.0)

C
       DO 305 J=1,32
       READ (1,30,END=900) (CELVAL(I,J),I=1,10)
   305 CONTINUE
C
       DO 310 J=1,2
       READ (1,30,END=900) (UCOST(I,J),I=1,10)
   310 CONTINUE
C
C      READ IN AVG REQ SIZE VALUES FROM INPUT DATA FILE
       READ(1,30,END=900) (RS(I), I=1,10)
C
       DO 320 J=1,32
       READ (1,40,END=900) (TADVD(I,J),I=1,2),TITEMS(J),TDOLAR(J)
  320  CONTINUE
C
   40  FORMAT (F11.2,3F9.0)
C
C      -----------------------------------------------------------------
C
C      WRITE THE INPUT DATA TO A FILE
C
       OPEN (6,FILE='OUT.TXT',STATUS='NEW')
C
       WRITE (6,50)
   50  FORMAT (20X,'  OCCUR - THE OCCURANCE OF CERTAIN DOLLAR DEMANDS ',
     *        'WITHIN A GIVEN PRICE RANGE'//)
C
CX     WRITE (6,60) ((OCCUR(I,J),I=1,10),J=1,32)
   60  FORMAT (' ',10F9.0)
C
       WRITE (6,62)
   62  FORMAT (///,30X,'                    THE INPUT VARIABLES ',
     *     //120('_'),/50X,'UNIT COST')
C
       WRITE (6,64) (UCOST(I,1),I=1,10)
   64  FORMAT (22X,'| ',10F7.0,' |     TOTAL      TOTAL ')
C
       WRITE (6,66) (UCOST(I,2),I=1,10)
   66  FORMAT (' ',6X,'TADVD RANGE',4X,'| ',10F7.0,
     *     ' |     ITEMS     ($000)')
C
```

3

```
      WRITE (6,67)
   67 FORMAT (128('_')/)
C
      DO 330 J=1,32
      WRITE (6,68) (TADVD(I,J),I=1,2),(OCCUR(I,J),I=1,10),
     *     TITEMS(J)
   68 FORMAT (' ',2F10.0,' | ',10F7.0,' | ',F9.0)
      WRITE (6,69) (CELVAL(I,J),I=1,10),TDOLAR(J)
   69 FORMAT (' ',20X,' | ',10F7.0,' | ',9X,F9.0)
  330 CONTINUE
C
      WRITE (6,67)
C
      WRITE (6,61) (RS(I), I=1,10)
   61 FORMAT (' ',' AVG REQ SIZE ',6X,' | ',10F7.0,' | ')
C
C     ------------------------------------------------------------------
C       INITIALIZATIONS
C
      OC=600
      HC=.20
C
      LAMBDA=0
      TEBOM=0
      FRCOST=0
      UCSTWT=0
      TV55DD=0
      TDVK = 0
      TVQR = 0
C
      SQRTA2=SQRT(REAL(2))
C
C     FOR COMPUTATION OF SIGMA1 (SHERBROOKE FORMULA)
C
      A =.321 + (.0125*4*13.5/12.)
      B =.583 - (.0045*4*13.5/12.)
C
C     ------------------------------------------------------------------
C
C     OBTAIN FROM THE USER THE SYSTEM-WIDE BACKORDER CONSTRAINT AND
C     INSTRUCTIONS ON SIGMA FACTORS, SAFETY LEVELS, ORDER QUANTITIES,
C     USE OF REQUISITION SIZES, AND Q REDUCTION FACTOR
C
      WRITE (*,72)
   72 FORMAT (' ENTER A VALUE FOR THE SYSTEM WIDE BACKORDER CONSTRAINT')
C
      READ (*,74)  BETA
   74 FORMAT (F20.0)
C
      WRITE (*,76)  BETA
      WRITE (6,76)  BETA
   76 FORMAT (//' THE SYSTEM WIDE BACKORDER CONSTRAINT IS ',F20.0//)
C
C     OBTAIN FROM THE USER A FACTOR TO BE USED IN ADJUSTING
C     SIGMA FOR PURPOSES OF SENSITIVITY ANALYSIS
```

```
C
      WRITE (*,2)
    2 FORMAT (' ENTER A MULTIPLICATION FACTOR FOR SIGMA: ')
      READ (*,3) SIGFAC
    3 FORMAT (F8.4)
      WRITE(*,4) SIGFAC
      WRITE(6,4) SIGFAC
    4 FORMAT (' THE MULTIPLICATION FACTOR FOR SIGMA IS  ',F8.4)
C
      WRITE (*,17)
   17 FORMAT (' ENTER INTEGER WEIGHTS W1,W2,W3 FOR SIGMA1,2,3 ')
      READ (*,18) W1, W2, W3
   18 FORMAT (3I4)
      WRITE(*,19) W1, W2, W3
      WRITE(6,19) W1, W2, W3
   19 FORMAT (' THE SIGMA WEIGHTS ARE: ',I4,'  ',I4,'  'I4)
C
      WRITE(*,5)
    5 FORMAT (' DO YOU WANT STRICTLY WILSON LOT SIZES FOR Q ? ',
     *        ' -  ENTER Y OR N ')
      READ(*,20) WLSNQ
C
      WRITE(*,6)

    6 FORMAT (' DO YOU WANT SAFETY LEVELS ? - ENTER Y OR N ')
      READ(*,20) SAFLVL
C
      WRITE(*,7)
    7 FORMAT (' DO YOU WANT TO APPLY AVG REQ SIZE ENGLISH ? ',
     *        ' - ENTER Y OR N ')
      READ(*,20) ARS
C
C     AVG REQ SIZE ENGLISH MEANS LAMBDA IS ADJ BY 1/SQRT(RS) AND
C     SYSTEM FILL RATE DEMAND WEIGHTING ADJ BY DIVIDING BY AVG REQ SIZE
C
C
C     ----------------------------------------------------------------
C
C     QUERY USER FOR A Q REDUCTION FACTOR (QRF) BETWEEN 0 AND 1.
C     THIS FACTOR WILL REDUCE EVERY Q(I,J) TO QRF x Q(I,J).
C
      WRITE (*,9)
    9 FORMAT (' ENTER A  Q  REDUCTION  FACTOR BETWEEN 0.0 AND 1.0 ')
      READ (*,11) QRF
   11 FORMAT (F6.3)
C
C     ----------------------------------------------------------------
C
C     CALCULATE THE AVERAGE ANNUAL $ SPENT ON THE UNITS WITHIN A GIVEN
C     CELL (AVGDPU)
C
      DO 340  J=1,32
C
      DO 350  I=1,10
C
```

```
      IF (OCCUR(I,J).EQ.0.)THEN
           AVGDPU=0.
           GO TO 350
      ENDIF
C
      AVGDPU = (CELVAL(I,J) * 1000) / OCCUR(I,J)
      IF (MOD(I,10).EQ.0) THEN
          WRITE (*,70) J,I,AVGDPU
C
   70 FORMAT (' WITHIN CELL ','(',I3,',',I3,')',' AVGDPU = ',F9.0)
      ENDIF
C
C     CALCULATE THE AVERAGE UNIT COST (C) FOR EACH CELL IN OCCUR.
C
      C(I,J) = (AVGDPU - TADVD(1,J)) / (TADVD(2,J) - TADVD(1,J)) *
     *        (UCOST(I,2) - UCOST(I,1)) + UCOST(I,1)
C
C     CALCULATE THE ANNUAL DEMAND (D) FOR EACH CELL IN OCCUR
C
      D(I,J) = AVGDPU / C(I,J)
      TD(I,J)=D(I,J)
C
C     CALCULATE THE DEMAND IN A LEADTIME (U)
C     BASED ON RATIO OF PLT TO 365, BY SMGC (AFLC DATA)
C
      IF(J.LE.6)  U(I,J) = D(I,J) * .88
      IF(J.GT.6.AND.J.LE.15)  U(I,J) = D(I,J) * 1.23
      IF (J.GT.15)  U(I,J) = D(I,J) * 1.53
C
C     CALCULATE THE VALUE OF 55 DAYS OF DEMAND FOR EACH CELL
C     AND SUM THIS VALUE TIMES THE MULTIPLICITIES
C
      V55DD(I,J) = D(I,J) * (55./365.) * C(I,J) * OCCUR(I,J)
C
      TV55DD = TV55DD + V55DD(I,J)
C
C     COMPUTE THE ORDER QUANTITY (Q) FOR EACH CELL IN OCCUR
C     BY FIRST CALCULATING THE WILSON LOT SIZE Q (WLSQ) AND, IF
C     DESIRED, INSURING THAT IT IS WITHIN A GIVEN RANGE, AND THEN
C     ESTABLISHING IT AS Q.
C
      WLSQ = SQRT (2 * D(I,J) * OC / (HC * C(I,J)))
      TWLSQ = WLSQ
C
      WLSQ = MAX (WLSQ, D(I,J))
      Q(I,J) = MIN (WLSQ, (D(I,J)*3))
C
      IF (WLSNQ.EQ.'Y') Q(I,J)=TWLSQ
C
C     CALCULATE THE RATIO OF Q/D
C
      QDU(I,J) = Q(I,J) / D(I,J)
C
C     SET VALUES FOR SIGMA BY TAKING A WEIGHTED
C     AVERAGE OF SIGMA1 (SHERBROOKE FORMULA),
C     SIGMA2 = U(I,J), AND SIGMA3 = AFLC DATA:
```

```
C
      VMRAT = 1 + A * U(I,J)**B
      SIGMA1 = SQRT (VMRAT*U(I,J))
      SIGMA2 = U(I,J)
      IF(J.LE.6) SIGMA3 = 3385.92
      IF(J.GT.6.AND.J.LE.15)  SIGMA3 = 225321.74
      IF(J.GT.15)  SIGMA3 = 1672072.5
C
C     WEIGHTING FACTORS TO CALIBRATE EMULATOR
C     TO ACHIEVE 55 DAYS SL AND REALISTIC EBOS
C
      THETA =(W1*SIGMA1 + W2*SIGMA2 + W3*SIGMA3)/(W1+W2+W3)
C
      SIGMA(I,J) = SIGFAC * THETA
      VTMR(I,J) =(SIGMA(I,J)**2)/U(I,J)
C
C     CALCULATE LAMBDA BY SUMMING FOR EACH CELL
C
      LAMBDA = LAMBDA + (SIGMA(I,J) * 0.2 * C(I,J) * OCCUR(I,J)) /
     *    (SQRTA2 * BETA)
C
 350  CONTINUE
 340  CONTINUE
C
C     ------------------------------------------------------------
C
C     CALCULATE THE SAFETY LEVEL FACTOR (K)
C
      DO 360 J=1,32
C
      DO 370 I=1,10
C
      IF (OCCUR(I,J).EQ.0.) THEN
            GO TO 370
      ENDIF
C
      IF (ARS.EQ.'Y') THEN
             TLAMBDA=LAMBDA/SQRT(RS(I))
             ELSE
             TLAMBDA=LAMBDA
      ENDIF
C
C     COMPUTE K USING EITHER LAMBDA STRAIGHT OR ADJUSTED BY
C     AVERAGE REQUISITION SIZE.
C     NOTE:  COMPUTATION OF K IS DELIBERATELY NOT CHANGED WHEN
C          Q REDUCTION FACTOR ARE USED.
C
      COMPLX = (SQRTA2 * Q(I,J) * .2 * SQRT(C(I,J))) /
     *        (.5 * TLAMBDA * SIGMA(I,J) *
     *        (1 - EXP(-1 * SQRTA2 * (Q(I,J) / SIGMA(I,J)) ) ) )
C
      IF (SAFLVL.EQ.'Y') THEN
         K(I,J) = (-1 / SQRTA2) * LOG (COMPLX)
         ELSE
         K(I,J) = 0.0
      ENDIF
```

```
C
C     NEGATIVE SAFETY LEVELS ARE SET TO ZERO.
C
      IF (K(I,J).LT.0.) K(I,J)=0.0
C
C     UPPER CONSTRAINT ON SAFETY LEVELS.
C
      IF (U(I,J) .LT. 3*SIGMA(I,J)) THEN
             SMALL = U(I,J)
             ELSE
             SMALL = 3*SIGMA(I,J)
      END IF
C
      IF (K(I,J)*SIGMA(I,J) .GT. SMALL)  K(I,J) = SMALL / SIGMA(I,J)
C
C     -------------------------------------------------------------
C
C     CALCULATE THE REORDER POINT
C
      R(I,J) = U(I,J) + K(I,J) * SIGMA(I,J)
C
C
C     COMPUTE EBO (I,J) = THE AVERAGE NUMBER OF UNIT BACKORDERS
C     IN PLACE FOR THAT COMPONENT.
C     FOR PURPOSE OF COMPUTING EBO'S AND FILL RATES, USE REDUCED Q'S.
C
      FACQ(I,J)=QRF*Q(I,J)
C
      PART = (1 - EXP (-1 * SQRTA2 * FACQ(I,J) / SIGMA(I,J))) *
     *      EXP (-1 * SQRTA2  * K(I,J))
C
      EBO(I,J) = (0.5 / 2) * (SIGMA(I,J)**2 / FACQ(I,J)) * PART
C
C     TAKE A SUM OF THE BACKORDERS * THE MULTIPLICITIES IN ORDER TO
C     DETERMINE THE AVERAGE TOTAL NUMBER OF BACKORDERS IN PLACE
C
      TEBOM = TEBOM + EBO(I,J) * OCCUR(I,J)
C
C     COMPUTE THE FILL RATE AND THE NON-FILL RATE
C
      NFR(I,J) = (0.5 / SQRTA2) * (SIGMA(I,J) / FACQ(I,J)) * PART
C
C     COMPUTE THE TOTAL DOLLAR VALUE FOR THE SAFETY LEVEL
C
      DVK(I,J) = K(I,J) * C(I,J) * SIGMA(I,J) * OCCUR(I,J)
      TDVK = TDVK + DVK(I,J)
C
C     COMPUTE THE DOLLAR VALUE OF THE REDUCTION IN ORDER QUANTITIES.
C
      TVQR = TVQR+(Q(I,J)-FACQ(I,J))*OCCUR(I,J)*C(I,J)
C
C     COMPUTE THE NUMBER OF DAYS WORTH OF SAFETY LEVEL FOR ONE ITEM IN C
C
      VKID(I,J) = K(I,J) * SIGMA(I,J) * 365./ D(I,J)
C
      FR(I,J) = 1 - NFR(I,J)
```

8

```
C
C     FOR LATER COMPUTATION OF THE SYSTEM-WIDE UNIT FILL RATE,
C     CALCULATE:
      IF (ARS.EQ.'Y')TD(I,J)=TD(I,J)/RS(I)
      FRCOST = FRCOST + FR(I,J) * TD(I,J) * OCCUR(I,J)
      UCSTWT = UCSTWT + TD(I,J) * OCCUR(I,J)
C
  370 CONTINUE
  360 CONTINUE
C
C     --------------------------------------------------------------
C
C     CALCULATE THE SYSTEM WIDE FILL RATE
C
      SWFR = FRCOST / UCSTWT
C
C     CALCULATE THE VALUE IN DAYS OF TOTAL SAFETY LEVEL
C
      TSL = TDVK*55/TV55DD

C     --------------------------------------------------------------
C
C     ----------- OUTPUT -----------------
C
C
      WRITE (6,78) LAMBDA, TEBOM, SWFR, TV55DD, TSL, WLSNQ,
     *     SAFLVL, ARS, QRF, TVQR
      WRITE (*,78) LAMBDA, TEBOM, SWFR, TV55DD, TSL, WLSNQ,
     *     SAFLVL, ARS, QRF, TVQR
      WRITE (*,76)  BETA
C
   78 FORMAT (//' THE VALUE FOR LAMBDA WHICH WAS CALCULATED IS ',F15.7,
     *        //' THE AVERAGE TOTAL NUMBER OF BACKORDERS IN PLACE IS '
     *        ,F20.2,//' THE SYSTEM WIDE FILL RATE IS ',F10.4,//
     * ' THE VALUE OF 55 DAYS DEMAND FOR THE WHOLE SYSTEM IS ',F15.2
     *  / , ' THE TOTAL DAYS OF SAFETY LEVEL FOR THE SYSTEM IS ',F15.2
     *  / , ' USING WILSON LOT SIZES EXCLUSIVELY - (',A1,')',
     *  / , ' NONZERO SAFETY LEVELS ALLOWED - (',A1,')',
     *  / , ' AVG REQ SIZE ENGLISH APPLIED  - (',A1,')',
     *  / , ' THE Q REDUCTION FACTOR IS  ',F6.3,
     *  / , ' THE VALUE OF THE ONETIME Q REDUCTION IS ',F15.2,/)
C
C
      WRITE (6,83)
   83 FORMAT (/////// 128 ('_'), // '  MULTIPLICITY      C          D ',
     * '           Q        Q/D         R         FR     ',
     * '    VTMR       EBO        K        V55DD      VKID      SIGMA',/)
C
C
      DO 400 J=1,32
      WRITE (6,67)
C
      DO 410 I=1,10
C
```

9

FORTRAN SOURCE CODE LISTING (CONTINUED)

```
      IF (OCCUR(I,J).NE.0.) QDU(I,J) = FACQ(I,J)/D(I,J)
C
      WRITE (6,85) OCCUR(I,J), C(I,J), D(I,J), FACQ(I,J),
     *     QDU(I,J), R(I,J),
     *     FR(I,J), VTMR(I,J), EBO(I,J), K(I,J), V55DD(I,J),
     *     VKID(I,J), SIGMA(I,J)
C
  85  FORMAT (' ',F10.0,3F11.2,F8.2,F11.2,F8.4,F9.0,F12.0,F8.6,F12.2,
     * 2F9.0)
C
 410  CONTINUE
 400  CONTINUE
C
      WRITE (6,67)
C
C     ----------------------------------------------------------------
C     CALCULATION TO ESTIMATE OVERALL AVG REQ SIZE
C
C     SS=0
C     TT=0
C     DO 801 I=1,10
C     DD=0



C     DO 800 J=1,32
C     DD=DD+D(I,J)*OCCUR(I,J)
C800  CONTINUE
C     TT=TT+DD
C     SS=SS+DD*RS(I)
C801  CONTINUE
C     OARS=SS/TT
C     WRITE(*,95) OARS
C 95  FORMAT (/'  OVERALL AVG REQ SIZE IS ',F7.2)
C
      GOTO 990
C
 900  WRITE(*,91)
  91  FORMAT (' ERROR ON THE READ FROM THE INPUT FILE.')
C
C
 990  WRITE (*,92)

  92  FORMAT (/' NORMAL TERMINATION............')
 999  END
```

LIST OF REFERENCES

1. Hanks, C. H., The Air Force Stock Fund and Aircraft Availability, Working Note AF301-4, Bethesda, Maryland: Logistics Management Institute, October 1984.

2. O'Malley, T. J., The Aircraft Availability Model: Conceptual Framework and Mathematics, Task AF201, Bethesda, Maryland: Logistics Management Institute, June 1983.

3. Kiebler, Kelvin K., Replenishment Budget Additives, Task ML409, Memorandum Report I, Bethesda, Maryland: Logistics Management Institute, January 1985.

4. Arnold, Major William D., "The Impact on Combat Capability of Recoverables Awaiting Parts - AWP the #1 Spares Problem," Proceedings of the USAF Logistics Capability Assessment Symposium (LOGCAS 82), Colorado Springs, Colorado: Headquarters Tactical Air Command, March 1982, pp. IV-57 – IV-71.

5. Headquarters, Air Force Logistics Command, "Decline in AFLC Fill Rates," (Staff Summary Sheet and Tabs, prepared by D. Kubicki, HQ AFLC/MMLSC), Wright-Patterson Air Force Base, Ohio: Headquarters, Air Force Logistics Command, 3 May 1984.

6. Supply Management Policy Group, Office of the Assistant Secretary of Defense (Manpower, Installations, and Logistics), "Secondary Item Weapon System Management," Final Report, Washington, D.C.: Office of the Assistant Secretary of Defense (Manpower, Installations, and Logistics), May 1985.

7. Muckstadt, J., "A Multi-Echelon Model for Indentured Consumable Items," Technical Report No. 548, Ithaca, New York: School of Operations Research, Cornell University, June 1982.

8. Sherbrooke, Craig C., VARI-METRIC: A Multi-Indenture, Multi-Echelon Inventory Model with EOQ Items, Phase I - Final Report, HQ AFLC/MMMA, Wright-Patterson Air Force Base, Ohio: Sherbrooke & Associates, July 1985.

9. Headquarters, Air Force Logistics Command, "Requirements Procedures for Economic Order Quantity Items," (EOQ Buy Budget Computation System-D062), AFLC Regulation 57-6, Wright-Patterson Air Force Base, Ohio: Headquarters, Air Force Logistics Command, 22 August 1984.

10. Department of Defense, "Procurement Cycles and Safety Levels of Supply for Secondary Items," DoD Instruction 4140.39, Washington, D.C.: Department of Defense, July 1970.

11. Presutti, V. J. and R. C. Trepp, "More Ado about Economic Order Quantities (EOQ)," *Naval Research Logistics Quarterly*, June 1970, pp. 243-251.

12. Sherbrooke, Craig C., Estimation of the Variance-to-Mean Ratio for AFLC Recoverable Items, Final Report, HQ AFLC/MMMA, Wright-Patterson Air Force Base, Ohio: Sherbrooke & Associates, January 1984.

Other Sources of Information on DoD Stock Fund Operations

Department of Defense, "Regulations Governing Stock Fund Operations," DoD Directive 7420.1, Washington, D.C.: Department of Defense, January 1967.

Hadley, G. and T. M. Whitin, Analysis of Inventory Systems, Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1963.

Hanks, C. H., W. H. Horn, and J. F. Olio, Stock Fund Operations in the Department of Defense, Task ML420 Final Report, Bethesda, Maryland: Logistics Management Institute, April 1985.

Office of the Assistant Secretary of Defense (Manpower, Reserve Affairs, and Logistics), Stockage Policy Analysis - Final Report," (Annex A, Part 1), Washington, D.C.: Office of the Assistant Secretary of Defense (Manpower, Reserve Affairs, and Logistics), August 1980.

Olio, John F., et al., Secondary Item Inventory Growth, Task ML401 Memorandum Report, Bethesda, Maryland: Logistics Management Institute, June 1984.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A162 995	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) THE INFLUENCE OF SYSTEMS SUPPORT DIVISION FUNDING AND SAFETY LEVELS ON AIRCRAFT AVAILABILITY		5. TYPE OF REPORT & PERIOD COVERED Final Report
		6. PERFORMING ORG. REPORT NUMBER LMI Task AF501-1
7. AUTHOR(s) Christopher H. Hanks		8. CONTRACT OR GRANT NUMBER(s) MDA903-85-C-0139
9. PERFORMING ORGANIZATION NAME AND ADDRESS Logistics Management Institute, 6400 Goldsboro Road, Bethesda, MD 20817-5886		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Headquarters, U.S. Air Force, Directorate of Logistics Plans and Programs, Logistics Concepts Division (HQ USAF/LEXY)		12. REPORT DATE October 1985
		13. NUMBER OF PAGES 45
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

"A" Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Consumables; Inventory Management; Management Indicators; Materiel Management; Repair Parts; Retail Supply; Resources-to-Readiness; Revolving Funds; Spares; Sparing-to-Availability; Stock Funds; Supply Performance; Supply Policy; Weapon System Management; Wholesale Supply.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Systems Support Division (SSD) of the Air Force stock fund finances wholesale and retail supply levels for the set of consumable repair parts assigned to the Air Force for management in the DoD supply system. This work describes how fluctuations in SSD funding are likely to affect aircraft availability rates. It shows that at current funding levels, a moderate, one-time reduction in SSD Obligational Authority (OA), if managed through temporary reductions in wholesale order quantities, is not likely to have a significant

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. Continued

effect on weapon system readiness. Aircraft readiness is more sensitive to SSD safety levels than to order quantity reductions. Deep or repeated cuts in SSD OA (because such cuts could force safety level reductions) can have more serious effects on aircraft availability. Thus, the small effect of a one-time cut does not mean that SSD budgets can, or should, be cut. In fact, SSD supply performance since 1980 suggests that the Air Force Logistics Command (AFLC) should be increasing SSD safety levels. The report includes source code (FORTRAN) for a PC-based analytic inventory model used to emulate the AFLC SSD requirements system, along with a 320-item "template" of unit cost and demand data for SSD items, used to calculate and project overall SSD supply performance. Keywords:

END

FILMED

2-86

DTIC